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ABSTRACT

Recommended for grades 10-12 physical, earth, or general science classes, this 5-7 day unit is designed to give students a general understanding of solar energy and its use as a viable alternative to present energy sources. Along with this technology, students examine several factors of solar energy which influence the choice of solar home site location and construction materials. The unit consists of four daily lesson plans (with rationale, objectives, and instructional strategies provided for each). Fry readability levels for two readings (Introduction to Solar Energy and Energy Efficiency Home Design for the Energy Conscious Consumer), process skills fostered, advanced teacher preparation, goals, objectives, planning guide, and evaluation suggestions are provided in the introduction. (Author/JN)

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Solar Energy in the Home

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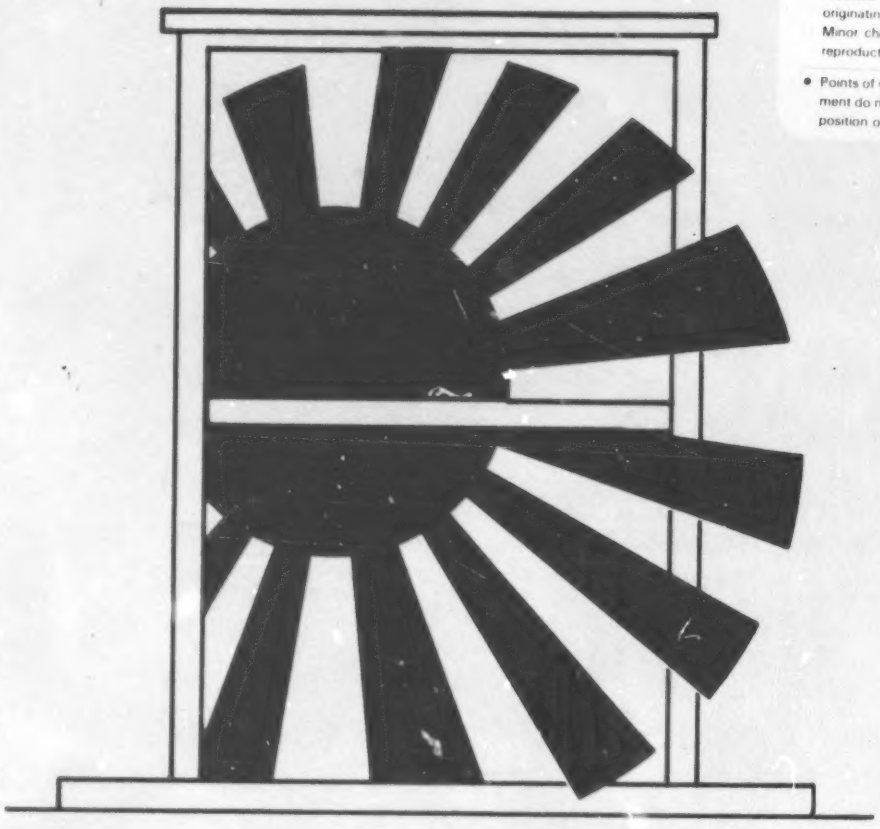

by

Allen A. Roeder
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(Revised)

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TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Recommended Subject: An introduction to passive solar technology for physical, earth, or general high school science courses.

Prepared for

The Nebraska Energy Office

SE039413

Help Conserve the Good Life of Nebraska

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To the Instructor . . .

"Solar Energy in the Home" is a unit designed to give students a general understanding of solar energy and its use as a viable alternative to present energy sources. Students will become familiar with basic solar technology and how it is being applied today. Along with this technology, students will examine several factors of solar energy which influence the choice of solar home site location and construction materials.

This unit consists of four daily lesson plans. Of course, you may choose to extend any one or all of the concepts involved or delete those which do not apply to your particular needs.

One feature of this revised unit is its sequenced approach as well as a "hands on" experiment for students. Another interesting feature is the readability level given for each student reading. This reading level is based on the number of syllables per hundred words and number of sentences per passage. This technique is taken from "A Readability Formula That Saves Time," Edward Fry. **Journal of Reading,** April, 1963, Vol. II, No. 7, pp. 513-16 and pp. 575-578. These reading level estimations will allow teachers the opportunity to perform some pre-reading exercises on vocabulary and concept development.

Finally, since material sources continue to change periodically, the source, **Energy Info—A Directory of Publications and Audio-Visual Materials From the Nebraska Energy Office,** contains a list of general topics available from the Nebraska Energy Office. You are invited to use the ordering page attached to this unit.

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Solar Energy in the Home

Abstract

In this learning package, you will investigate solar energy alternatives for the home. Through selected readings and investigation, the student will become aware of passive solar technology that is available today.

Recommended Level

Grades 10-12

Academic Area

Physical, earth, or general science

Readability Ratings (Fry)

"Introduction to Solar Energy" — 11 years 3 months
"Energy Efficiency Home Design for the Energy Conscious Consumer" — 8 years 4 months

Time Required

5-7 days

Process Skills

—Observing
—Recording
—Measuring
—Demonstrating
—Graphing
—Interpreting

Advanced Teacher Preparation

Obtain: Filmstrip "Harnessing the Sun"
National Georgraphic, No. 0-3249

Read: **Energy Info- A Directory of Publications and Audio Visual Materials From the Nebraska Energy Office,** 1981.

Goals

1. Students should recognize that solar energy is a viable alternative to the use of fossil fuels for home heating.
2. Students will become familiar with basic solar technology.
3. Students will become aware that solar technology is being applied in the world today.
4. Students will become familiar with factors which influence the selection of solar home site location and construction materials.

Student Objectives

1. The student will name three (3) advantages of solar energy.
2. The student will name two (2) factors limiting today's use of solar energy.
3. The student will list four (4) factors affecting heat retention.
4. The student will name two (2) materials with good insulating properties.
5. The student will list three (3) factors to be considered when siting and planning an energy efficient home.
6. The student will describe two (2) applications of landscaping with trees in an energy efficient home design.
7. The student will demonstrate an understanding of the following solar energy technologies:
   A. Heating and cooling
   B. Photovoltaic conversion

Planning Guide

Day 1

1. Show filmstrip — "Harnessing the Sun"
2. Discuss ancient to modern uses of solar energy
3. Assign reading, "Introduction to Solar Energy"

Day 2

1. Discuss advantages and disadvantages of using solar energy
2. In-class reading "Solar Heating and Cooling"
3. Discussion of reading
4. Pre-lab — Heat Retention Investigation

Day 3

Laboratory — Heat Retention Investigation.

Day 4

1. Post-lab — Heat Retention Activity
2. In-class reading, "Energy Efficient Home Design for the Energy Conscious Consumer"
3. Discussion of reading
4. Information Search: Either provide students with reading materials on the following topics or use this time to have students gather information about: a) solar electricity from photovoltaic conversion, b) hydroelectric power, or c) other solar energy applications. These readings will provide information for eventual discussion.

Evaluation Suggestions

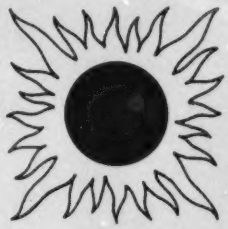
This unit allows individual teachers to develop their own instruments for evaluation.

OPTIONAL: Have the student design a solar energy efficient home considering the following factors:
1. Orientation of the home on a building site.
2. Use of natural landscaping.
3. Building materials and insulation.
4. Home should be a pleasant place for human habitation.

Please allow more time to complete this packet if this method of evaluation is chosen.

"Introduction to Solar Energy"

"The heat of the universe is produced by the sun"
Leonardo Da Vinci



the sun as an ultimate source of energy

Da Vinci was fairly accurate in his statement about our source of heat. We know now that there are billions of suns heating the universe. If we go back in time from when the mythological Prometheus first stole fire from heaven, to modern man's burning of fossil fuels, we become aware of the sun as man's source of energy.

three main waves of light

Sunshine is composed of electromagnetic waves. These waves travel through space at a rate of 300,000 kilometers per second. The three main waves are invisible infrared, visible light, and invisible ultraviolet.

effects of ultraviolet light

Ultraviolet light has a wavelength shorter than visible light. It can be of benefit to man, aiding in the formation of vitamin D, and sterilization of some pathogens. Overexposure to ultraviolet radiation is harmful, causing sunburn and skin cancer. Most of the ultraviolet light is absorbed by the earth's atmosphere.

Infrared waves are longer than visible light. These are heat waves which can readily pass through the atmosphere but are absorbed by glass and water.

visible light and its uses

Visible light is that part of the electromagnetic spectrum which we can see. Most visible light waves reach the earth's surface where they are absorbed and converted into heat. This heat is then reradiated back into the atmosphere in the form of infrared radiation. This radiation is readily absorbed by carbon dioxide and water vapor thus warming the earth's atmosphere. Note that the atmosphere is heated directly by heat radiation from the earth and only indirectly by the energy of sunlight. This is known as the "greenhouse effect" and is one of the main principles of solar heating.

fossil fuels

Photosynthesis is the link between the sun, food, and fossil fuels. It is the process by which plants use sunlight to manufacture carbohydrates from water and carbon dioxide in the presence of chlorophyll. This is the beginning of the food chain. Fossil fuels are the plant and animal remains which have been turned into coal, petroleum, and natural gas by the slow action of heat, pressure, and aging. This source of stored sun energy supplies 95 percent of the energy used by civilized man. Although reports on reserves differ, they all agree that someday, early in the next century, man will have used up the earth's supply of petroleum and natural gas. This leaves coal as our only remaining fossil fuel. Of the three fossil fuels, coal causes the greatest amount of pollution when burned.

coal

alternatives

Since man is using fossil fuels faster than nature can replenish them, he/she must produce alternative sources of energy. Conservation methods and improved technology for recovery of fossil fuels only increases the life of our reserves. They do not solve the ultimate problem of what to do when they are depleted.

many uses of solar energy

problems with solar energy

Man has made use of solar energy in the past. Wind, caused by unequal amounts of sunlight falling on different geographical locations, provided man with the energy needed to move ships around the world, and to turn windmills to provide energy for various tasks. The sun also produced combustible materials such as wood for production of heat energy. Man has also been aware of the two main disadvantages of direct solar energy. The first is that sunlight is diffuse. It is spread out and must be collected by some means. The second drawback in sunlight is intermittence. It is only available during clear days. This creates two problems for scientists to resolve. One is to develop a way to store solar energy for later use and the other is to convert sunlight into energy economically.

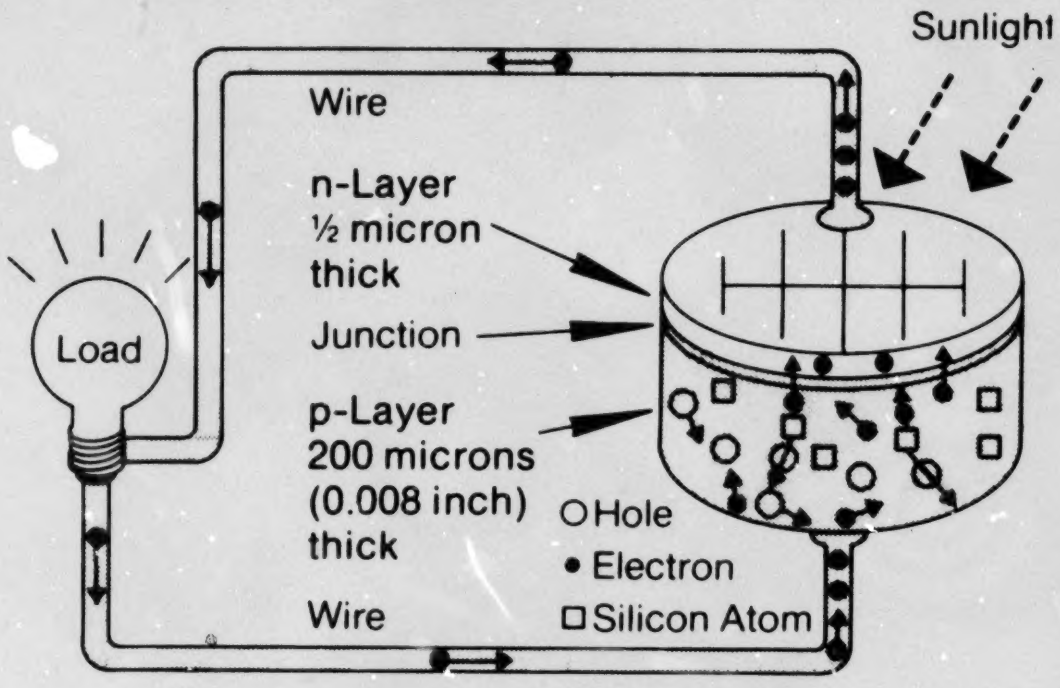
advantages of solar energy

life expectancy of the sun

application of solar energy for everyday use

When man resolves these problems, he/she will realize three major advantages that solar energy has over nuclear, fossil fuels, and hydroelectric power. First, solar energy is readily available throughout the world. Unlike nuclear and fossil fuels, sunlight is not found in concentrated areas scattered over the earth's surface. This results in fewer distribution problems and prevents the exploitation of one country by another. The second advantage is that solar energy is almost inexhaustable. The estimated solar energy reserve is five billion years, the life expectancy of the sun. Finally, solar energy is non-polluting. Solar power generation does not produce any by-product which decreases the environment's ability to support life.

By applying the "greenhouse effect" and the absorption/reflection of light, (by light and dark surfaces), the technology already exists for space and hot water heating. Photovoltaic cells have the capability to convert sunlight into electricity. At present these cells are hand crafted and inefficient, making them an expensive source of electrical power. The technology is being developed for mass-production and to increase their efficiency. With this in mind, solar energy will be a practical energy source for the home.



A Solar Cell at Work

Sunlight penetrates the ½-micron-thick n-layer (a micron is one-millionth of a meter) and liberates electrons near the junction of the two layers. These electrons are collected by the wire attached to the front of the cell and can be used as ordinary direct current to do work.

Solar Energy—
Heat Retention Investigation

Concept
Different substances retain heat for various amounts of time.

Question
What factors affect a substance's ability to gain or lose heat?

Objectives
The student will list four (4) factors affecting heat retention.
The student will record temperature readings.
The student will graph results of the experiment.

Process Skills
Observing, measuring, recording, graphing, interpreting, demonstrating.

Time
Thirty (30) minutes for the actual experiment.

Background
You will need to supply or have each student group bring in 100 ml of two different substances for testing in this experiment. Most ideally, there should not be any duplication of these materials. Anything they would like to try should be allowed. Perhaps they may discover a new insulator?

Materials
(4) 250 ml beakers
(4) thermometers
100 ml water
100 ml sand
1 timing device
100 ml each of two different substances
1 light source with reflector and 200-250 watt bulb
Class set of graph paper
Transparencies showing graph results
Overhead projector

Procedure/Sequence
1. Place 100 ml of each substance in a separate beaker.
2. Put a thermometer in the center of each substance.
   (NOTE: The bulb should be buried in the substance and the water thermometer bulb should be shielded from the light source.
3. Set the four beakers equal distance (10cm) from the light source.
4. Read and record the initial temperature reading.
5. Turn on the light source.
6. Record temperature readings every minute for 10 minutes.
7. After 10 minutes, turn off and remove the light source.
8. Continue recording temperature every minute for an additional 20 minutes.
9. Plot your data on a graph with temperature as a function of time.

Data Graphs

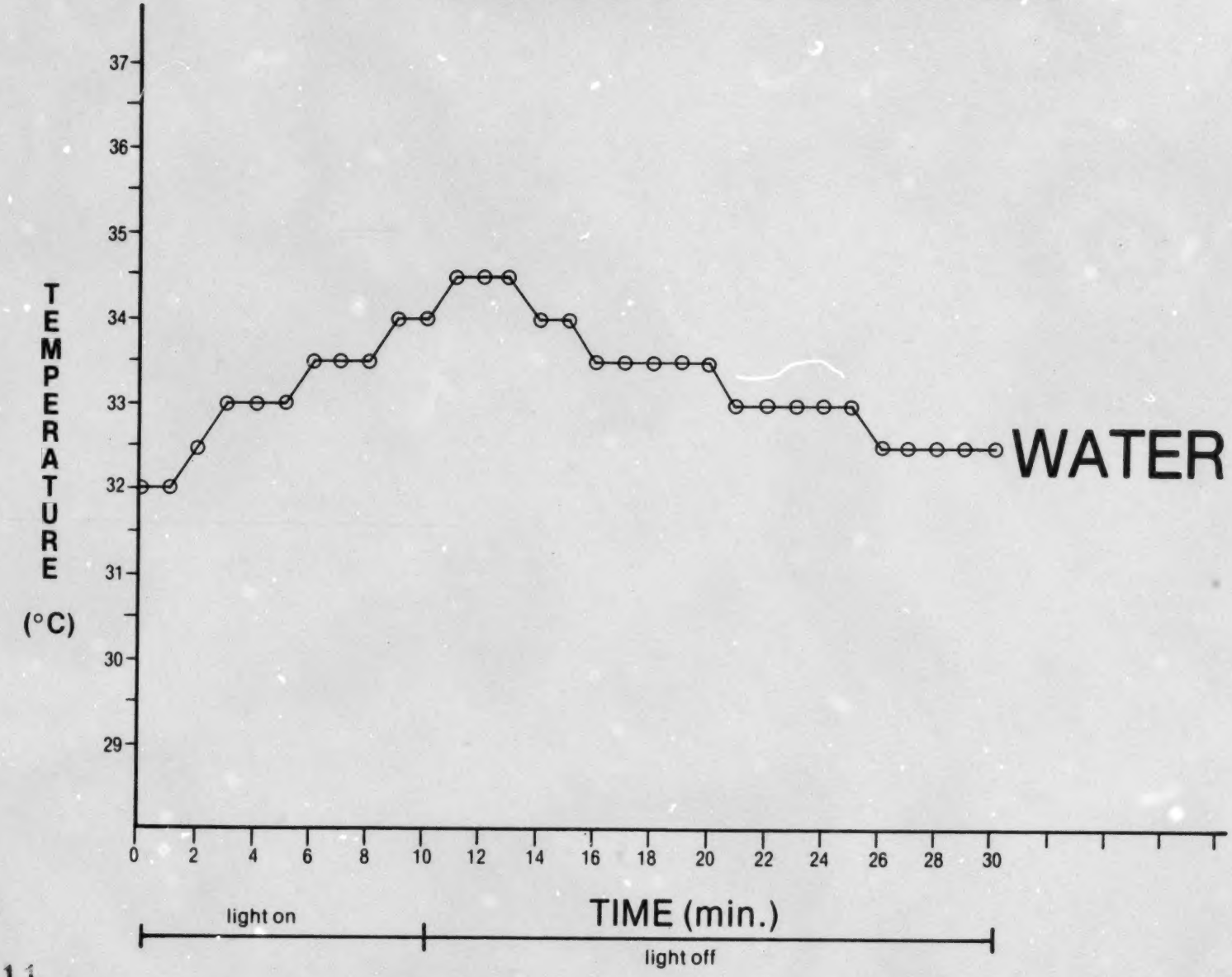
Instructor: The following four pages can be made into transparencies. These transparencies show the heat retention of the substances:

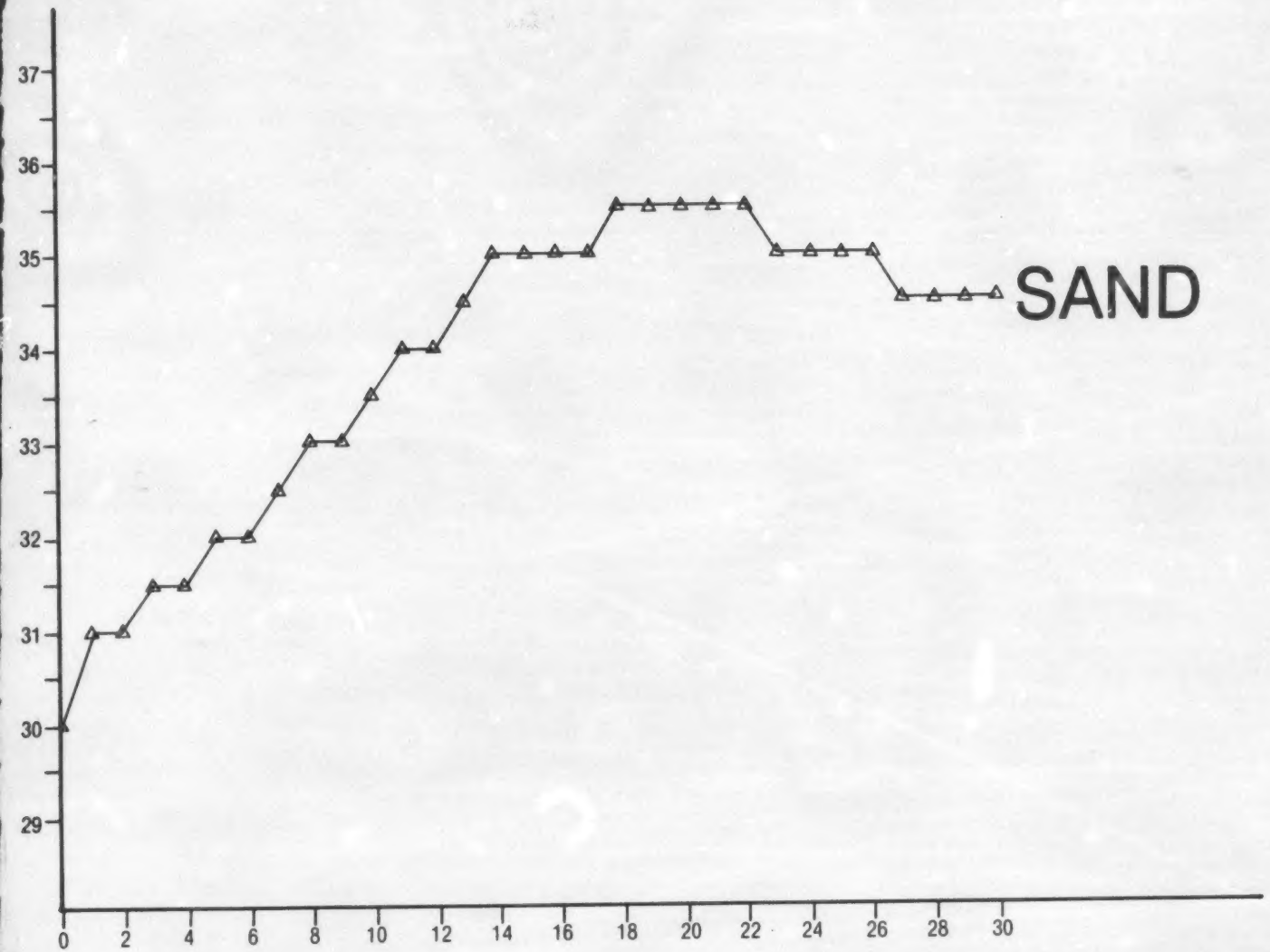
1) Water
2) Sand
3) Beads
4) Dirt

These graphs can be shown separately or they can be superimposed (by laying one upon another) for comparative purposes.

These transparencies will assist you in giving students some idea of how to make their graphs as well as examples of additional elements students may bring to class.

HEAT RETENTION OF SUBSTANCES

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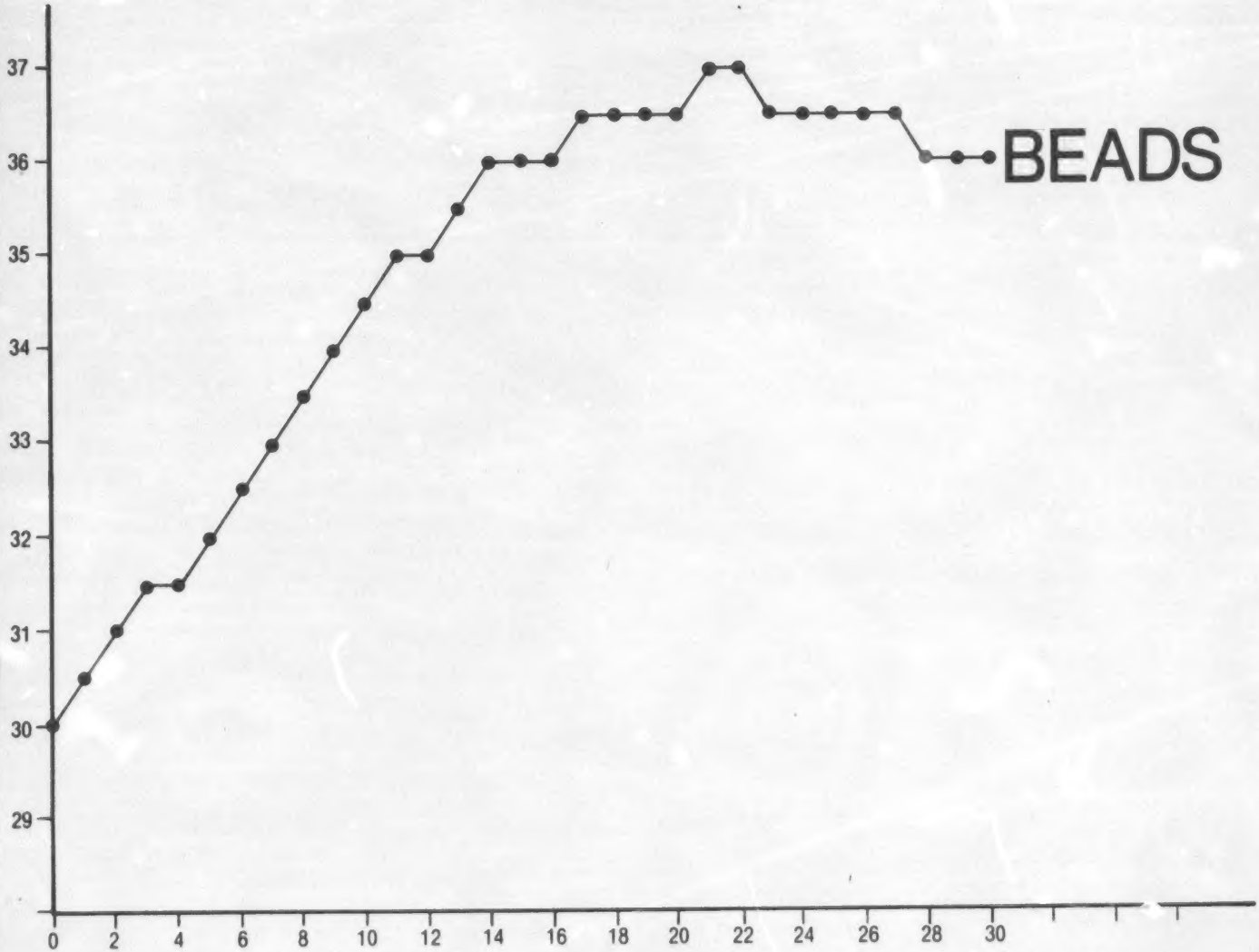
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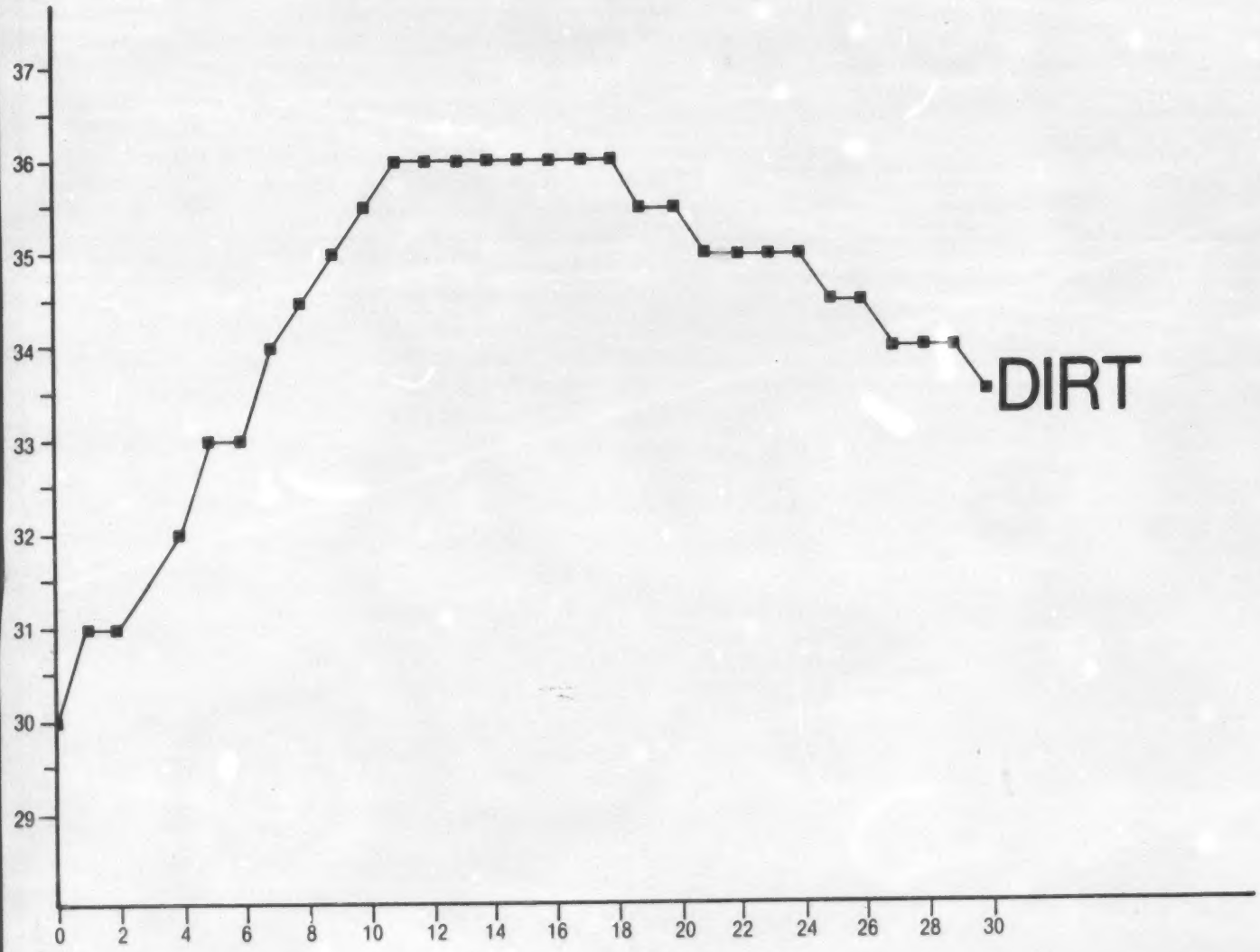
BEADS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DIRT

Data:

HEAT RETENTION ACTIVITY

TIME (min.)	water	sand	beads	dirt
0	32.0	30.0	30.0	30.0
1	32.0	31.0	30.0	31.0
2	32.5	31.0	31.0	31.0
3	33.0	31.5	31.5	31.5
4	33.0	31.5	31.5	32.0
5	33.0	32.0	32.0	33.0
6	33.5	32.0	32.5	33.0
7	33.5	32.5	33.0	34.0
8	33.5	33.0	33.5	34.5
9	34.0	33.0	34.0	35.0
10	34.0	33.5	34.5	35.5
11	34.5	34.0	34.0	36.0
12	34.5	34.0	35.0	36.0
13	34.5	34.5	35.5	36.0
14	34.0	35.0	36.0	36.0
15	34.0	35.0	36.0	36.0
16	33.5	35.0	36.0	36.0
17	33.5	35.0	36.5	36.0
18	33.5	35.5	36.5	36.0
19	33.5	35.5	36.5	35.5
20	33.5	35.5	36.5	35.5
21	33.0	35.5	37.0	35.0
22	33.0	35.5	37.0	35.0
23	33.0	35.5	36.5	35.0
24	33.0	35.0	36.5	35.0
25	33.0	35.0	36.5	34.5
26	32.5	35.0	36.5	34.5
27	32.5	34.5	36.5	34.0
28	32.5	34.5	36.0	34.0
29	32.5	34.5	36.0	34.0
30	32.5	34.5	36.0	33.5

Questions:

1. Why is it important all containers are equidistant from the light source?
2. Why is it important that you have the same amount of each substance?
3. Which substance absorbed heat the most rapidly?
4. Which substance absorbed heat the least rapidly?
5. Which substance lost heat the most rapidly?
6. Which substance retained heat longest?
7. What factors affect a substance's ability to gain or lose heat?
8. Based on your data, which substance would be most ideal for use in a solar home and why?

Answers to Questions:

1. So they all receive the same amount of radiation.
2. The mass of a substance will affect the heat loss or gain.
3. Depends on student data.
4. Depends on student data.
5. Depends on student data.
6. Depends on student data.
7. Color, chemical composition, air space between particles, density, surface area, surrounding air currents, etc.
8. Depends on data; the resistance to heat gain or loss would be a prime factor in answering this question. Encourage student discussion on this question. (practicality, availability, special handling problems, price, etc.)

"Energy Efficient Home Design for the Energy Conscious Consumer"

some ways to make a home energy efficient

An energy efficient home incorporates passive design ideas and/or solar energy systems in its planning, construction, and use. Conventional energy conservation features such as insulation in the right places, double glazing of windows, and weatherstripping at all openings, increase energy efficiency.

"Passive design ideas" are defined as design approaches or ideas that:

1. use solar energy naturally,
2. contain little mechanical hardware,
3. require little or no energy themselves,
4. usually are low in cost.

use the natural environment

Nature is our ally, in efficient home design. We must understand that builders should consider what nature dictates, and not always what style might dictate. To build energy efficient homes is to understand both the assets and liabilities of the natural environment. Without this understanding, our homes will be at war with natural forces when peaceful co-existence would be more advantageous, both ecologically and economically.

design with nature in mind

The energy efficient home will be designed with some basic facts in mind. The design must consider proper site location and position, earth and landscape buffers, careful use of glass, and natural ventilation. Preceeding any design, correspondence with the nearest weather bureau is a must. If the home is going to complement nature, you must first get to know nature.

Nebraska's weather affects home design

Nebraska, because of its location and geography, is treated to wide differences in weather conditions; from stifling heat to bone-chilling cold. Winds cross our predominately flat plains with little or nothing to stop or deter them. Building for consistent weather conditions may be the rule in the far North or South, but Nebraska gets its share of both the best and worst from both regions. The Nebraska home must be designed to withstand the extreme effects of these climatic variations.

using what nature has provided

There are methods for using what nature has already provided. For example, one might build an underground home and heat it with an open fire. You could select a site abundantly dotted with large shade trees. You could avoid a windy hilltop and find shelter in the side of a hill. You could look for a nearby pond or lake to serve as a natural cooling system in the hot summer months.

adapting to the environment

Although it might be best to utilize nature exactly as you find it, it may not always be practical to do so. The underground cave may not provide the open air feeling that you desire, you may want an outside view and you might not want to be tied down feeding a wood burning stove. Trees may not always be growing where you would like them and a nearby pond or lake may be even more difficult to find.

items for consideration

There are, however, ways to use nature to your advantage without letting nature take advantage of you. In selecting a site, consider the slope of the land, the direction the home will face, and trees as possible windbreaks.

positioning the home toward the south

In a rural setting, try to select a location with the land sloping slightly to the south. Position the home so that the winter winds will strike the back of the house. Plan your view from the southerly exposure so that windows on the north side will be few in number, small in size, and functional for ventilation. Summer winds tend to come from the south. With this design, you can use the cooler winds of evening and night to remove the daylight heat. If a directly south facing home is not possible, a shift to a more easterly direction is better than building toward the west because a west facing home will tend to be overheated by direct rays of the sun in the hottest part of the summer day.

With or without a southerly slope to work with, consider the wind breaking effect of trees located to the north of the home. Wind travels approximately five times the height of the obstacle it has to pass over. Therefore, if the trees to the north of the home are twenty feet tall, the wind will travel over the trees and continue to travel "high" for approximately one-hundred feet (5 times 20 equals 100 feet). Your home is therefore protected from the brunt of the wind if it is located within one-hundred feet of the trees. Coniferous (evergreen) trees are best for a northerly wind break because they do not lose their leaves.

using trees for windbreaking

A city building site has its own special problems when considering building exposure. You should strive for a frontal southern exposure. Be aware of other structures surrounding your lot that may block out the sun. A solar efficient home is of little value if the sun never shines on it. Unusual wind currents may tunnel around other structures and strike your house continuously. You must observe these conditions yourself; the weather bureau cannot help you with isolated conditions. Trees become even more important in cities by moderating not only winds, but temperatures carried by the concentration of hard surfaces—streets and buildings.

conditions to consider when building

An energy efficient home must be constructed to weather all seasons. As we plan for reduced fuel usage in the cold months, we are also planning for a comfortable indoor environment during the hottest summer months. In all aspects of construction and material usage, natural forces will again be taken into account.

all season efficiency

We usually think of insulation to keep warm air "in" and cold air "out." Insulation also works by increasing your home's resistance to external heat. A well insulated home, even with outside temperatures as high as 98°F, should stay cool until early evening when (hopefully) cooler winds and natural ventilation will remove the accumulated heat.

insulation used to resist heat

Before you buy any insulation, shop around. Read the accompanying literature on all types of insulation. You will usually see reference made to "R-value." R-values refer to a material's ability to retard the flow of heat; the larger the R-value, the more the material resists heat flow. R-values are additive. If one inch of the material has an R-value of 4, then two inches of the material has an R-value of 8, and so forth.

"R-value"

As the cost of fuels continues to increase, so does the optimum R or overall resistance to heat flow for your home. Now an overall resistance of 25 or 30 may be a wise long-term investment. Remember that it is much less expensive and difficult to add sufficient insulation while constructing a home than to add it later.

add insulation when building

Nebraska's recommended "R" ratings are:

Ceiling = 25 - 38
Walls = 16 - 22
Floors = 20 - 25

When planning your home's insulation needs, remember to consider the direction the walls are facing. The south wall probably will not require as much insulation as the north wall. If your site location took wind currents into consideration, you are ahead of the insulation game. It is much better to prevent high velocity winds from reaching the surface to your structure than try to insulate against these winds.

planning: site, location, and direction

No matter how well insulated your dwelling may be, how well sheltered from the wind it may be, about 50 percent of the total indoor heat is lost through air infiltration. A general "tightening up" of your home is required to save this otherwise wasted heat. This is true of both new construction and older dwellings. Weatherstripping is required around doors and windows. All cracks in walls and foundations should be caulked as well as all areas around non-opening windows. During winter heating or summer cooling seasons, close off all unused hallways and rooms.

ways to cut down unwanted air infiltration

Windows lose from five to ten times more heat per square foot than do walls or ceilings. The importance of taking action to reduce this tremendous waste of heat cannot be overstressed.

location of windows

natural ways to heat and cool

location of air vents

function of air vents

benefits of passive solar

absorbing and distributing heat

storing heat in masonry walls

benefits of a greenhouse

Traditionally, windows have been oriented to face the street or road. Windows in an energy efficient home should be oriented to the sun as well as to the need for light and the floorplan of the room. Your largest windows should be on the south side; there they can capture the warming rays of the winter sun. Of course, in the summer, the warm rays are not wanted, so the home design must incorporate an overhang above these windows that will block the high summer sun but not the lower winter sun. Trees may also play a role in your energy efficient design. Large trees that provide welcome shade in the summer and drop their leaves in the fall to allow the winter sunshine to pass, are an attractive addition to your southern exposure.

To decrease heat loss through existing windows, add storm windows or double panes of glass if they are not already there. Caulk and weatherstrip around all cracks no matter how small. Movable insulating shields, or shutters should be placed over windows at night in the winter.

A small foyer may be added to your design. (A foyer may also be added quite readily to an existing structure.) This foyer will create a still air-space that will drastically reduce the amount of cold air that enters the house (or leaves in the summer) when the door is opened or closed. This low cost addition to your design (or present home) will greatly improve your home's total energy efficiency.

Natural cooling of your home occurs when cool air is allowed to enter and replace warm air. If you increase the velocity of the air passing through your home, you will increase the cooling effect. If the inlet is the same size as the outlet, the cooling effect will be the same as a gentle breeze; however, if you reduce the size of the inlet to one-half the size of the outlet, your air movement will be rapid enough to provide comfort even on highly humid summer days. (Don't worry, you still will not generate an "in house" tornado).

Position your vents so that the intake is on the windward size of the house (the side that the wind hits) and the outlet is on the leeward (sheltered) side. In many areas, the prevailing wind direction changes from day to night. If you live in such an area, locate your inlet vents on the side of your home where the cool evening breezes originate. Cool air will flow through the inlet vents and force hot air out of the higher outlet vents. Shrubs which shade (not block) your inlet vents will increase their cooling effect.

Passive solar collectors are simply windows and masonry elements located on the south side of your home. Although these items may seem simple, if they are incorporated into a well located and insulated home, they can provide from fifteen to one-hundred percent of your heating needs directly from the sun.

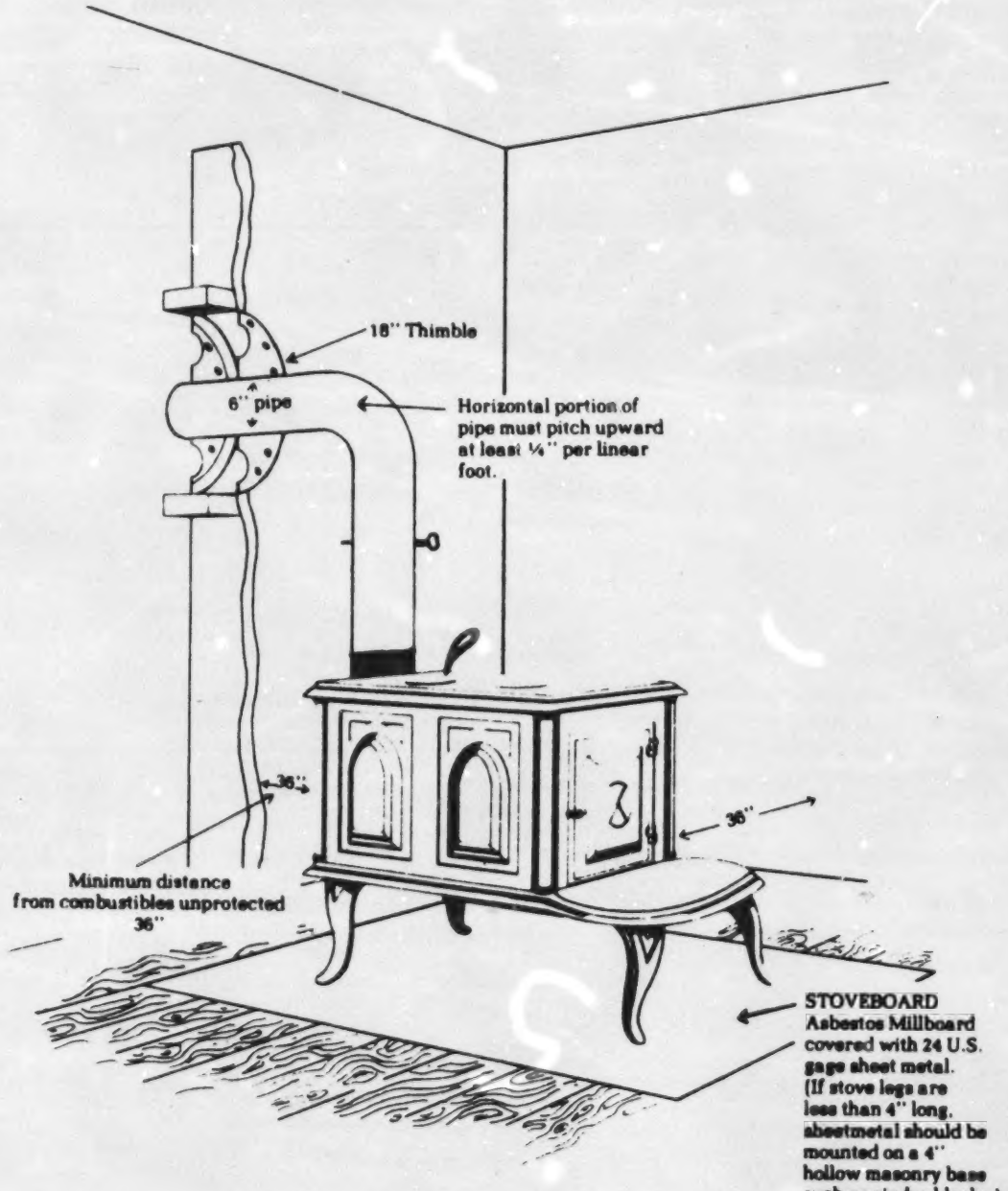
Masonry floors and walls do an excellent job of storing the sun's heat. If the floors are brick or concrete, allow the sun to shine on uncarpeted areas. These areas will absorb the sun's heat and return it to your house throughout the day and into the night.

A masonry wall will also store heat. Sunlight will strike the back of a south room early in the morning and late in the afternoon. While a masonry wall can be structurally functional, it can also be strikingly beautiful, if well designed. As a heat absorber, the masonry wall allows you to increase the amount of south-facing windows without overheating your interior in the daytime. If your interest leads you in such a direction, this wall might incorporate a large aquarium, the water providing excellent heat retention capacity. You might even use the aquarium to provide a source of high quality protein for your family.

Adding a greenhouse to your home provides both additional winter heat and a suitable environment to grow food and/or flowers all year long. If you want a greenhouse, it is substantially less expensive to add it to your home rather than to build a separate structure. Add your greenhouse directly to your south- or east-facing wall. The heat, stored in the masonry or rock floor of your greenhouse, can be moved into your house with a small fan. Again, shutters or insulating curtains are needed to retain heat at night.

Heating with wood is another solar supplement that you may want to consider as part of your design. A fireplace, while aesthetically pleasing, is not an energy efficient device and therefore is not for your energy efficient home. Air-tight wood burning stoves, however, are extremely efficient heating devices, and most of them now provide for a view of the flame just as with a fireplace.

wood burning stoves


18" Thimble
6" pipe
Horizontal portion of pipe must pitch upward at least ¼" per linear foot.
36"
36"
Minimum distance from combustibles unprotected 36"
STOVEBOARD
Asbestos Millboard covered with 24 U.S. gage sheet metal. (If stove legs are less than 4" long, sheetmetal should be mounted on a 4" hollow masonry base such as cinder blocks.)

Resources

Materials Written for the Unit

**"Energy Efficient Home Design for the Energy Conscious Consumer"

**"Heat Retention" Laboratory

**"Introduction to Solar Energy"

Pamphlets

Energy Info—A Directory of Publications and Audio-Visual Materials from the Nebraska Energy Office, 1981.

This pamphlet contains related information on such topics as:

Passive Solar,

Photovoltaics,

Residential Energy Efficiency (Landscaping).

****Factsheet #7, Solar Heating and Cooling.** National Science Teachers Association, 1977.

Filmstrip with Cassette

*"Harnessing the Sun." **National Geographic Society.** #03249, 1977. 13 minutes.

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* Only one copy of this resource is required for classroom viewing.
**(A classroom set of each of the materials listed above is required).

Supplement

Books

Build-it Book of Solar Heating Projects. Foster, William F. Tab Books, 1977.

Design for a Limited Planet. Skurka, Norma and Jon Naar. Ballantine Books, 1976.

Energy: Global Prospects 1985-2000. Workshop on Alternative Energy Strategies. McGraw-Hill Book Co., 1977.

Natural Solar Architecture: A Passive Primer. Wright, David. Von Nostrand Reinhold Co., 1978.

Magazines

Better Homes & Gardens. Volume 57, Number 3, March, 1979.
National Geographic. Volume 149, Number 3, March, 1976.

Pamphlets

Energy Efficient Building Design. Wynnyckyj, Paula. University of Nebraska Press, 1977.

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Solar Energy In The Home